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Quarterly Report No. 16

From October 1, 1963 through January 31, 1964

on

BALLISTIC PROTECTIVE BUOYANT MATERIALS

U. S. NAVAL SUPPLY RESEARCH AND DEVELOPMENT FACILITY

BUREAU OF SUPPLIES AND ACCOUNTS, DEPARTMENT OF THE NAVY

Contract No. N140(138)72793B

Mellon Institute Research Project No. 4388-4

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PITTSBURGH 13, PA.

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No. 4388-4

TABLE OF CONTENTS

Page

A. BUOYANCY EVALUATIONS

I. Pre-hydrophobed 1.0 dpf Acrilan

The difficulty encountered by textile processors in the application and curing of the Decetex-104 upon the Acrilan fibers had prompted the Chemstrand Company in cooperation with this laboratory to attempt the hydrophobing of the fibers during their preparation. As a result, silicone-coated staple fibers have been produced and furnished to this laboratory for verification and testing.

a. Sample Needled Felts Prepared by the Chemstrand Company

Three groups of samples were obtained from the Chemstrand Company containing hydrophobed 1.0 dpf Acrilan staple fibers. The material as received at Mellon Institute, was in the form of needled felts. Unfortunately a scrim material was incorporated (for stability), thus preventing complete evaluation. The three groups of samples were tested for their buoyant behavior; two were inadequate, but the third showed exceedingly great promise. The hydrophobed staple fibers that were used in felts that were found to be buoyant, were subsequently furnished for our testing.

b. Sample Batts Prepared at Mellon Institute

The hydrophobed 1 denier Acrilan fibers, designated ATX-966 by the Chemstrand Company, were carded into batts in the laboratory, and then subjected to the bulk-type 60 gr. microstatic buoyancy test. The resultant buoyancy curve as presented in Figure I, was extremely encouraging. The buoyancy value for the material after one hour was almost 8 lb/lb. of fibers, and even after 24 hours of immersion it maintained a bouyancy greater than 5.5 lb/lb. of fibers.

1. Effect of Additional Curing

Our past experience with the Decetex-104 finish on the Acrilan fibers has often shown that additional curing, above that usually applied during commercial processing, was necessary. Therefore samples of the ATX-966 fibers were cured in the laboratory oven, one group for a period of ten minutes at 135°-140°C and the second for a period of 30 minutes at the same temperature range. These recured samples were then carded and again tested by the micro-buoyancy technique. The curves are presented in Figure I and may be compared with the fibers which had been tested on the "as-received" basis. The group that had been cured additionally for 10 minutes presented the greatest buoyancy of the three. After 1 hour of immersion, these battings maintained a buoyancy of 8 lbs/lb. of fibers; and over a 24-hour period, were greater

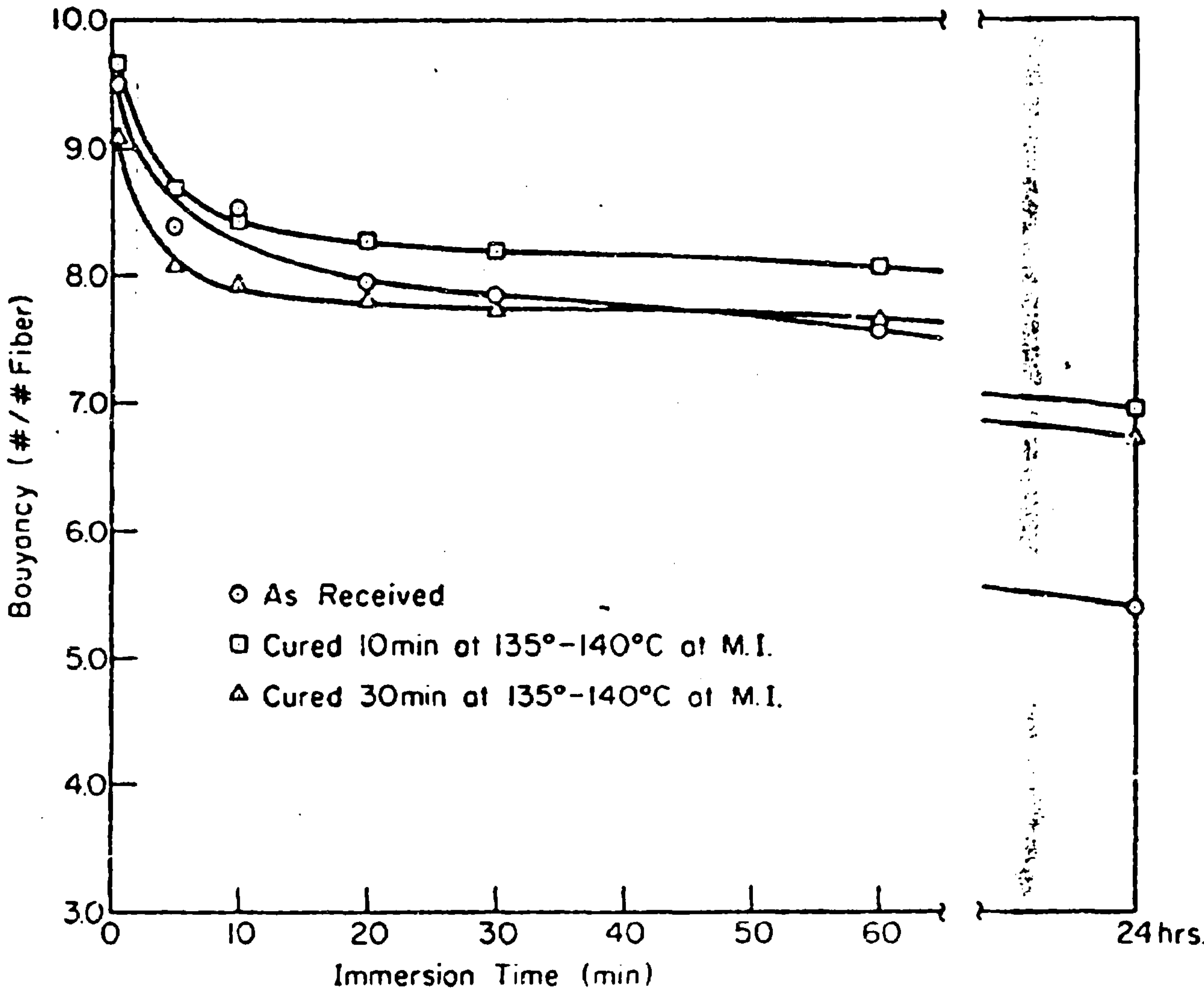


FIG I

MICRO STATIC BUOYANCY (60gm. SAMPLES) OF
BATTS CONTAINING CHEMSTRAND'S ATX-966 FIBERS

than 7.0 lbs/lb. of fibers. The fibers that had been cured for 30 minutes, although ultimately better than the "as received material," were consistently lower in buoyancy than those cured for 10 minutes. We feel that the reason for this is the loss in bulk (loss in crimp) caused by the excessive curing. Since the ATX fibers have shown such great promise, larger quantities for commercial runs were prepared by the Chemstrand Company.

2. Effect of Water-Repellent/Catalyst Ratio

The required ratio of the Decetex-104 silicone water-repellent to its catalyst is 5:1. During the initial application of this water-repellent to the 1 denier Acrilan continuous filament by the personnel of the Chemstrand Company, an error was committed in that the water-repellent bath was prepared at a ratio of 50:1. However, even after this apparent inadequate application, the felts prepared from the coated fibers gave evidence of satisfactory water repellency. Consequently, a comparison was made between two groups of felts, one group coated with a 5:1 ratio of the Decetex repellent to its catalyst and the other at the erroneous ratio of 50:1. The results obtained are presented in the accompanying Figure II. It can be seen that the felts prepared on the 50:1 basis are slightly lower in buoyancy than similarly-prepared felts from the 5:1 bath. This situation exists for those felts which are on the as-received basis; that is to say,

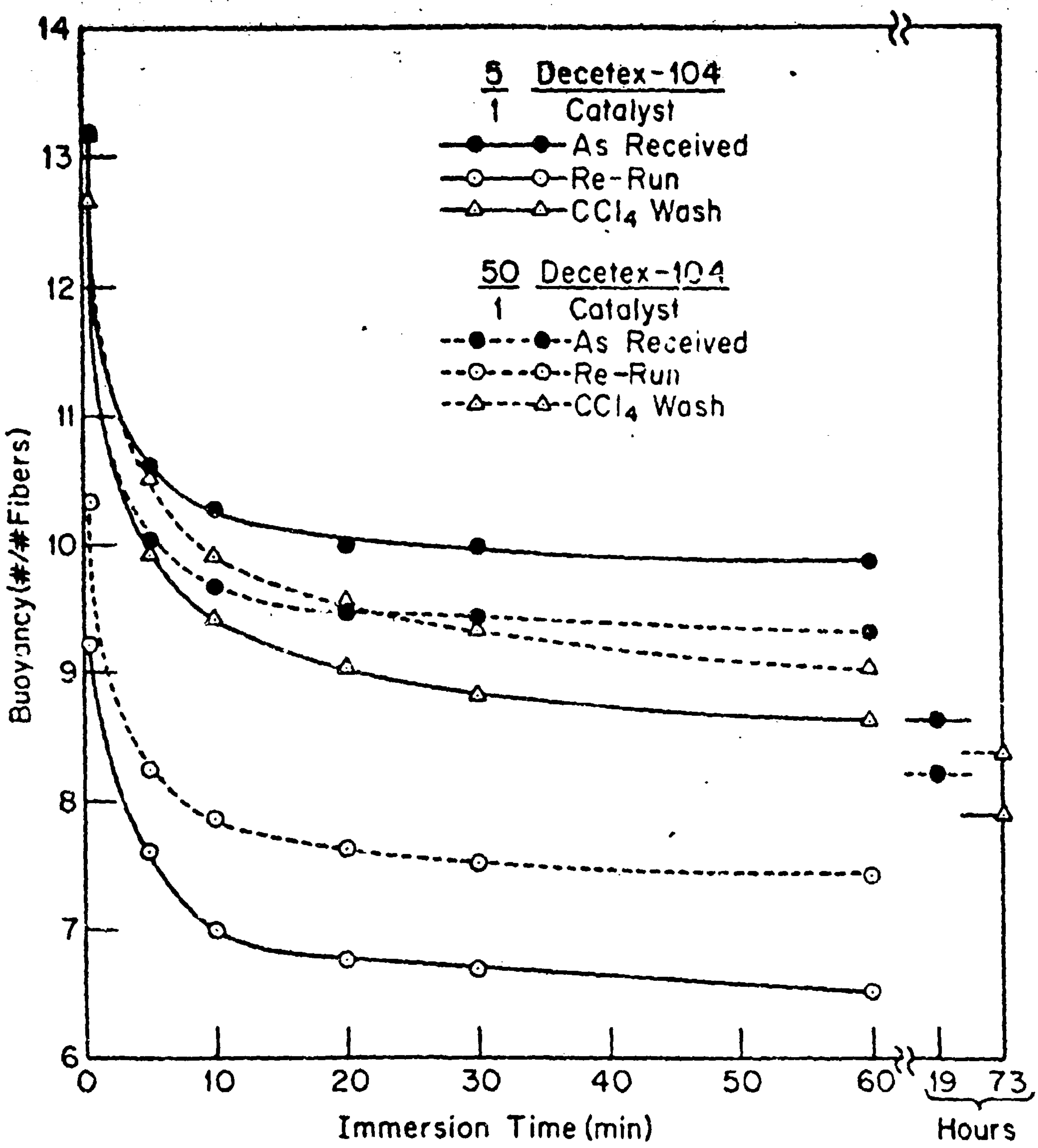


FIG. II

EFFECT OF THE WATER-REPELLENT/CATALYST RATIO UPON THE STATIC BUOYANCY OF PRE-HYDROPHOBED 1.0 dpf ACRILAN NEEDLE-FELTS, COMPARTMENTED

before any renovation of rerunning were attempted. It is possible that the slightly lower buoyancy may be due to the fact that a fairly large amount of unreacted Decetex-104 silicone remained on the surface of the fibers and hindered the full water-repellency.

c. Needled Felts Prepared at Mellon Institute

1. Up-grading by Compartmentation

Verification was made of the beneficial effect of compartmentation upon the laboratory-needled felts. The two curves that are presented in Figure III are representative of this phenomenon. Samples of the prehydrophobed needled felts were prepared identically, all had thicknesses of 0.39 inches and areal densities of 14.5 oz/yd^2. Half of the material was cut into 6 inch strips and then recombined with polyethylene film as separators. Although the results (Figure III) are not as dramatically spectacular as our previous results, it is still quite evident that compartmentation does increase the buoyancy of the felts.

(a) Effect of Felt Thickness

Two groups of compartmented needled felts were prepared using the ATX prehydrophobed fibers. Both samples maintained identical areal densities of 14.5 oz/yd^2. The only difference between the two was in the actual thicknesses, in one case 0.39 inches thick and in the other

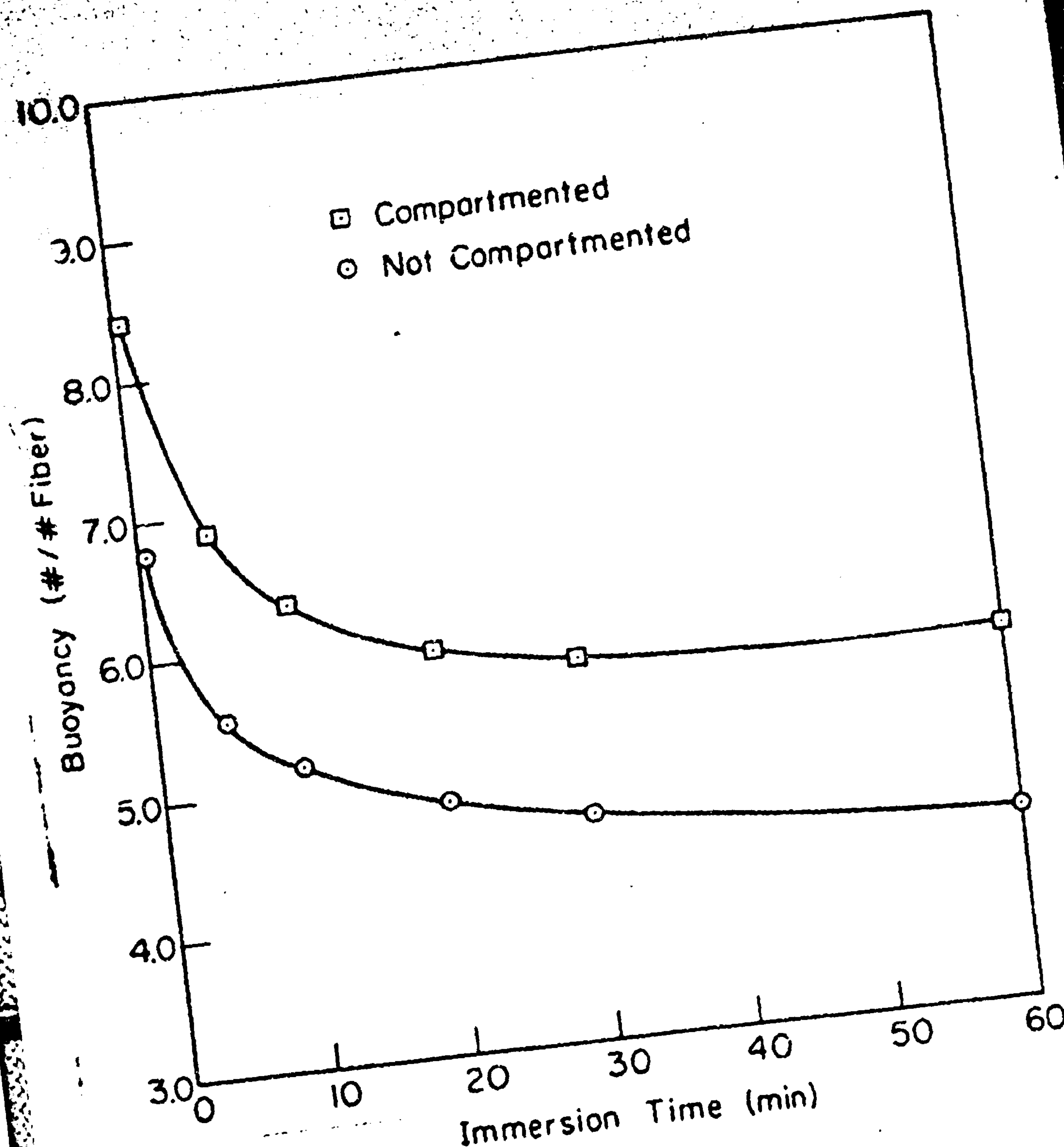


FIG. III

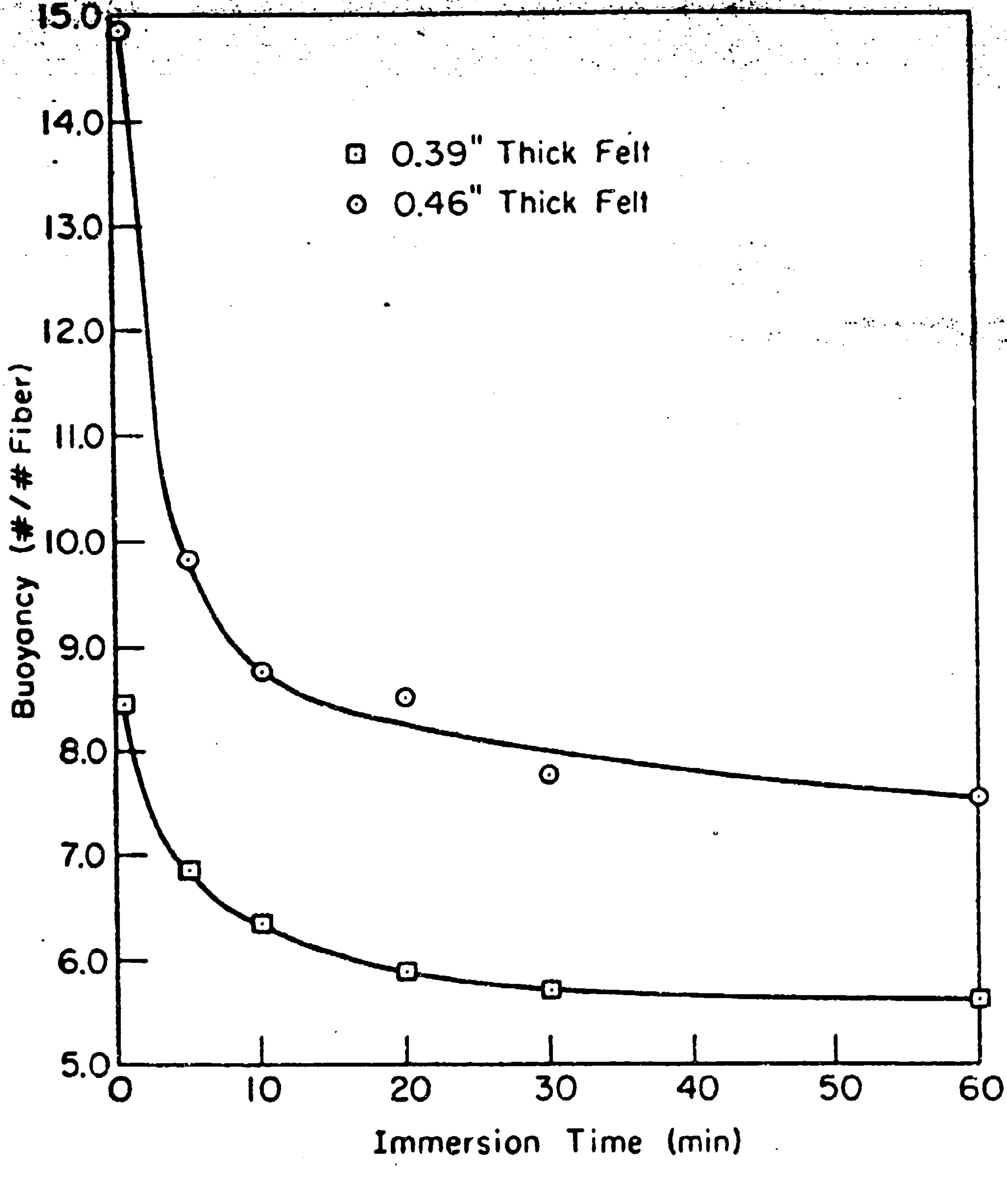
EFFECT OF COMPARTMENTATION UPON BUOYANCY
ATX-PRE-HYDROPHOBED 1.0 dpf ACRILAN NEEDLED FELT

0.46. The representative static buoyancy curves for these materials may be seen in Figure IV. Although the over-all loss in buoyancy for the immersion period of 60 minutes is quite large for the thicker samples, the actual buoyancy is still greater than that of the 0.39 inch thick felt. Since it had been decided to use a liner of approximately 0.5 inches in thickness for the main portion of the navy jacket, the results we obtained with the 0.46 inch felt were encouraging.

(b) Variations in the Needle-Felting Technique and the Effect Upon Buoyancy

The two main variables encountered in the felting of materials by means of the needle loom are the amount of needle penetrations per square inch, and the depth of penetration of the needles through the batting into the bedplate. The effect of the depth of penetration (of the needles into the bedplate) upon the buoyancy of the needled felts was investigated first. It was found that up to a bedplate penetration of 0.25 inch, no effective binding or interlocking of the fibers was obtained. The felts resulting from this incomplete binding were found to have poor cohesive characteristics, and were easily pulled apart. In addition, the interstices between the fibers were evidently so large that the water-repellent (that had been placed on the fibers) was not fully effective in preventing the penetration by water. To examine the effect of greater penetrations upon

Figure IV



EFFECT OF FELT THICKNESS UPON BUOYANCY
COMPARTMENTED NEEDLED FELTS CONTAINING ATX FIBERS

the felts, three groups of prehydrophobed fiber batts were prepared and then subjected to varying depths of needle penetrations. Such parameters as areal density (14.5 oz/yd^2), thickness (0.44-0.46 inches) and number of needle penetrations/in^2 were kept constant so that the results of the bouyancy tests would reflect mainly upon the depth of penetration of the needles through the battings and into the bedplate. In Figure V buoyancy curves are presented which show the effect due to this variation in bed-plate penetrations. An examination of these curves indicates that as the needle penetrates the samples to a greater depth, the buoyancy decreases. This, of course, holds true only for those range of values that were selected; namely, from 0.50 inch to 0.62 inch. To clarify the term bed-plate penetration, it is defined as that portion of the needle that has passed through the bottom of the batting and extends below the base plate of the needle loom. Of course, as the depth of penetration increases, there is more interlocking of the fibers and dense felts are obtained. This also means that thinner felts are obtained, and since initial buoyancy is related to the thickness of the sample, less buoyancy is evident.

(c) Effect of Laundering

A compartmented needled felt which had been processed from prehydrophobed fibers was laundered in the laboratory using a commercial detergent and tap water. To make the laundering action upon the felt more

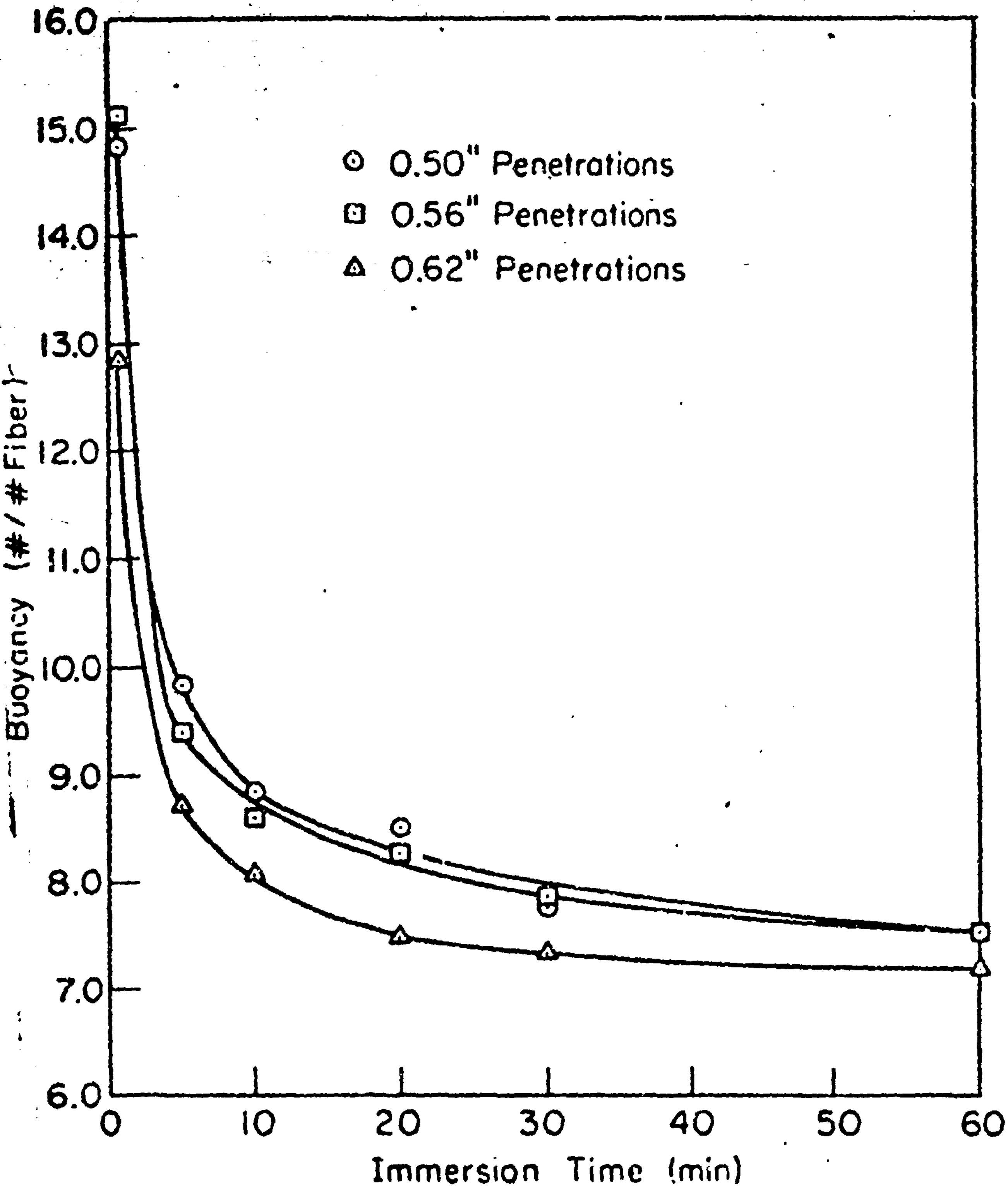


FIG. V

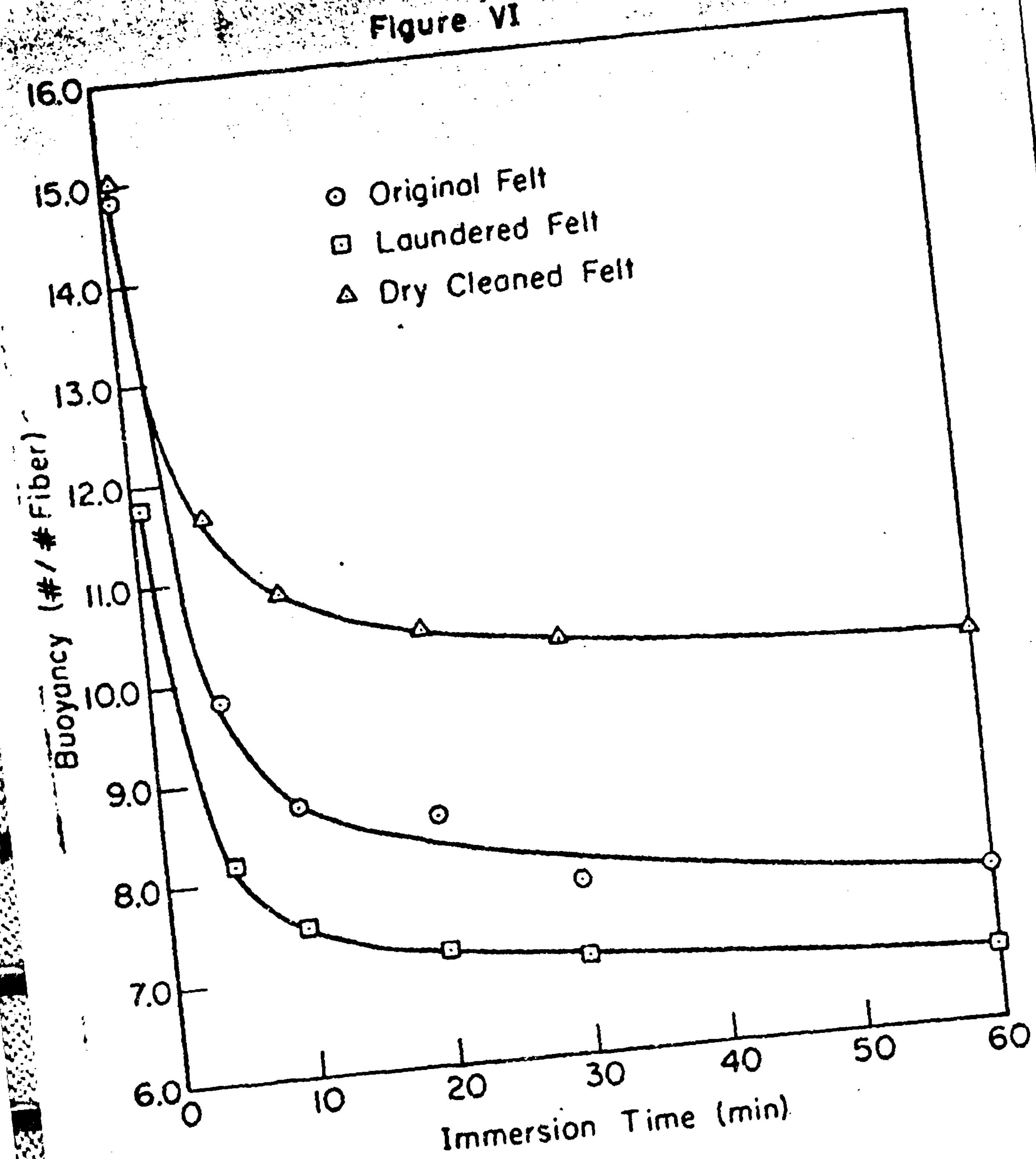
EFFECT UPON BUOYANCY DUE TO VARIATIONS IN BED-PLATE PENETRATIONS BY THE NEEDLES DURING FELTING COMPARTMENTED FELTS CONTAINING ATX FIBERS

vigorous, cover cloths were excluded. Since any detergent left in the felt would mask or hamper the water-repellency, the material was rinsed well. After drying in a laboratory oven, the felt was made up into samples and subjected to the static buoyancy test. In Figure VI the resultant buoyancy of this laundered felt is compared with that of the material before washing. Although there is some decrease in the buoyancy of the felts after laundering, the loss is not that significant to hamper the use of the material as a liner. The decrease may be attributed to the fact that the laundered samples became thinner resulting in the lowering of the initial buoyancies. It is to be remembered, also, that the use of cover cloths or liners would help preserve the integrity and surface characteristics of the felts.

(d) Commercial Dry-Cleaning

To determine the durability of the prehydrophobed fibers and their finish to organic cleaning solvents, a quantity of the fibers was dry-cleaned commercially. These were then processed into compartmented needled felts in the laboratory and tested for their buoyancy. It was found that the felt showed no significant buoyancy. Another group of virgin ATX (prehydrophobed) fibers was cured at 135°-140° for 30 minutes and then dry-cleaned commercially. It was thought that a lack of curing of the water-repellent may have been the cause for the elimination of the buoyancy.

Figure VI



EFFECT OF LABORATORY RENOVATION UPON BUOYANCY
COMPARTMENTED NEEDLED FELTS CONTAINING ATX FIBERS

However, compartmented felts prepared from these fibers were also without buoyancy.

Our previous experience with commercial dry-cleaners led us to the conclusion that the ingredients that were used may have masked the water-repellency. Consequently, felts which had been prepared by the latter method were then washed in the laboratory with carbon tetrachloride. The felts responded to this final cleaning. The buoyancy test proved the effective presence of the water-repelent. The data accumulated in these three separate trials are presented in Table I.

Subsequent discussion with commercial dry-cleaners has revealed the fact that most do not use 100% clean organic solvent. In many cases water and a detergent are present, as well as other supposedly beneficial agents such as moth-proofing compounds. The compartmented felts had been contaminated by either the detergent or the moth-proofing agents which effectively masked the water repellency. It is therefore necessary that in the future all such felts be dry-cleaned with pure dry-cleaning agents.

(e) Laboratory Renovation

Figure VI shows the effect of laboratory renovation upon the buoyancy of compartmented needled felts containing prehydrophobed fibers. Both the water-laundering and the dry-cleaning (perchloroethylene) were

Table I

Effect of Dry-Cleaning Upon Buoyancy

Compartmented Needled Felts Containing ATX Fibers

Immersion Time (Min.)	Buoyancy (#/# Fibers) Dry-Cleaned Commercially	Cured at 135°-140°C for 30 Min Dry-Cleaned Commercially	Cured at 135°-140° for 30 Min. Dry-Cleaned Commercially Washed with CCl_4 in the Lab
0.5	0	0	10.00
5			6.26
10			5.39
20			4.61
30			4.21
60			3.71

performed in the laboratory using a domestic washing machine. The buoyancy exhibited by the dry-cleaned felt is outstanding. This effect may have been caused by the removal of certain contaminants applied during the original preparation of the fibers, such as anti-static agents or unreacted (or partially reacted) silicone water-repellent. The results depicted in Figure VI unquestionably prove that both laundering and dry-cleaning are acceptable methods for renovating the ATX (pre-hydrophobed) needled felts.

d. Commercial Preparations

The next logical step in the research program was to obtain a large quantity of the pre-hydrophobed 1 denier Acrilan for processing at various textile plants. The Chemstrand Company made available approximately 500 lbs. of the material and portions of this were sent to various textile processors.

1. Laboratory Acceptance Test

Prior to shipping the pre-hydrophobed commercial Acrilan to commercial processors, it was necessary to check the adequacy of the water-repellency in the laboratory. Compartmented needled felts were prepared from random samples of the hydrophobed Acrilan and their static buoyancies obtained. In Figure VII a representative curve of the

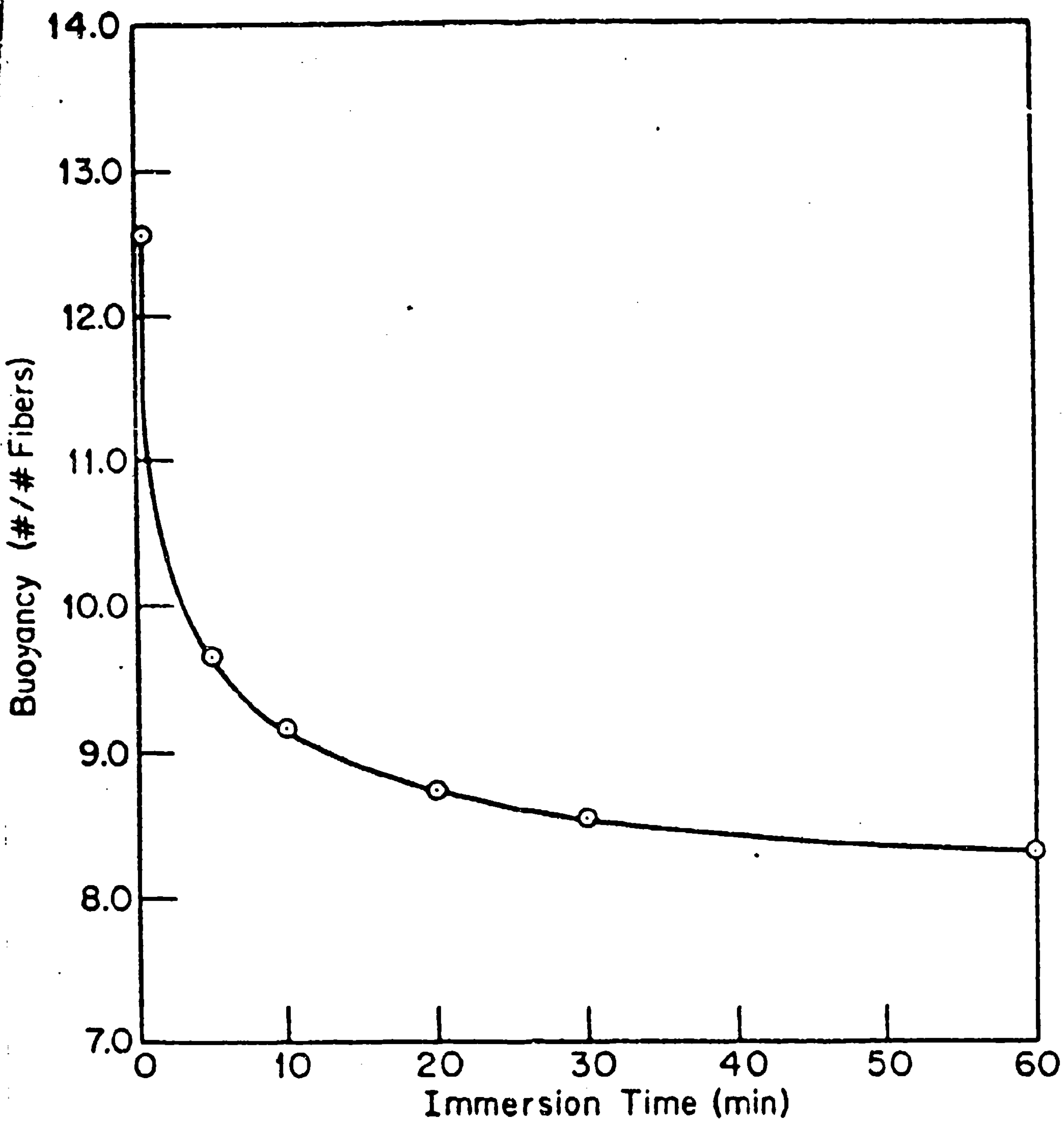


FIG. VII

STATIC BUOYANCY OF LABORATORY PREPARED COMPARTMENTED FELTS USING THE PRE-HYDROPHOBED 1.0dpf ACRILAN FIBERS DESTINED FOR COMMERCIAL PROCESSING

buoyant effectiveness of the samples is given. It can be seen that the buoyancy was more than adequate.

2. The Stearns and Foster Company

The Stearns and Foster Company of Lockland, Cincinnati, Ohio, prepared compartmented needled felts using the commercially coated pre-hydrophobed 1 denier Acrilan fibers. Visual examination of the samples show that difficulty had been encountered in the initial carding (opening) step. It appeared that a combination of carding and air-deposition must have been used because of the presence of fibrous aggregates which eventually were found to be deleterious to the buoyancy efficiency. The results of buoyancy evaluations on The Stearns and Foster material are presented in Figure VIII. The buoyancy of the original felts (as-received basis) is relatively low compared to the buoyancy of the felts prepared from the same material in the laboratory. After drying the samples that had been tested, they were rerun and showed a remarkable increase in buoyancy. This may be attributed to the closer packing of the aggregates of fibers because of the pressure of the water during the original test. It is also interesting to notice that an upgrading in the buoyancy of the original samples was accomplished by dry-cleaning.

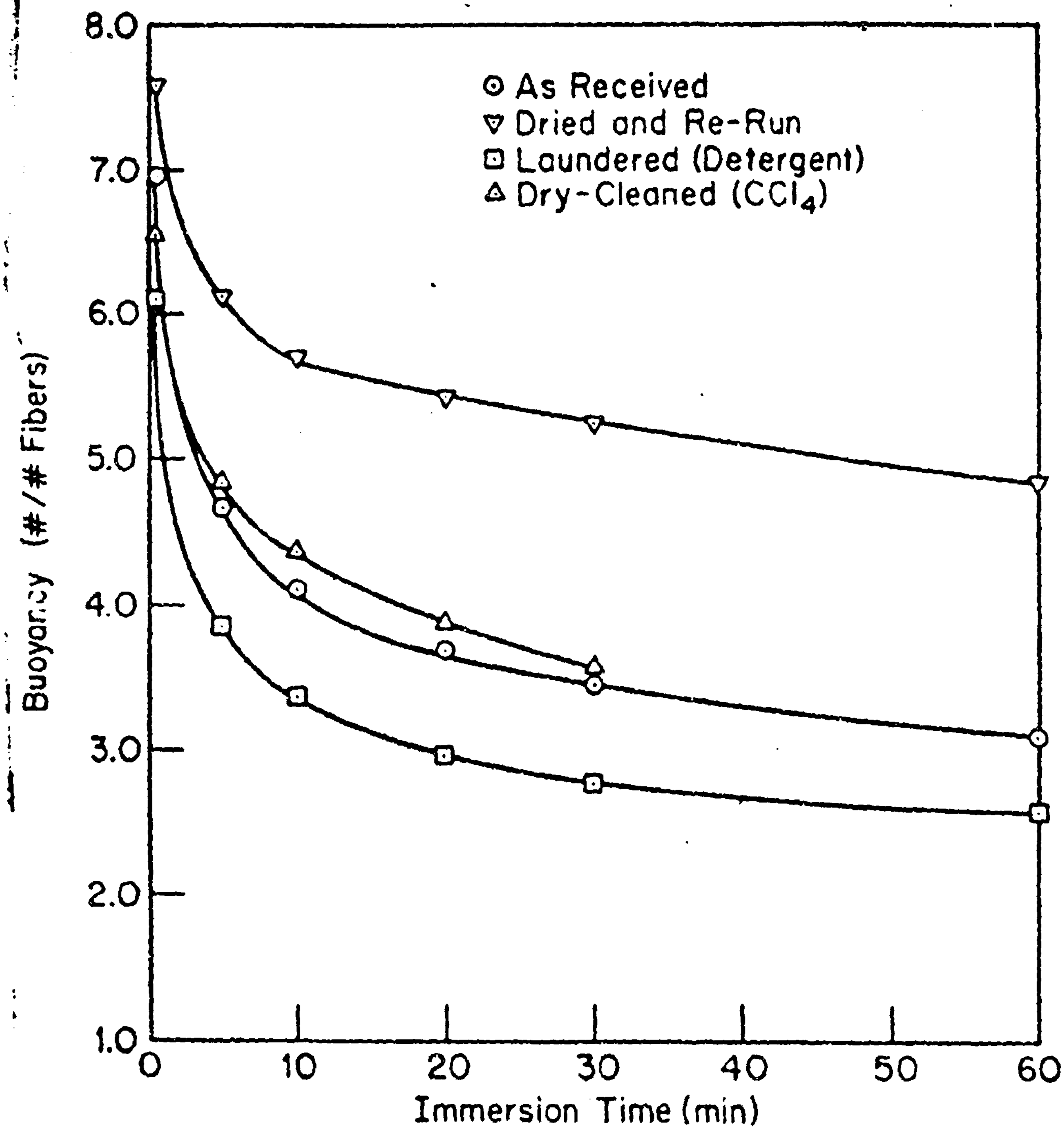


FIG. VIII

STATIC BUOYANCIES OF COMPARTMENTED NEEDLED FELTS, CONTAINING PRE-HYDROPHOBED 1.0 dpf ACRILAN FIBERS, PREPARED BY THE STEARNS AND FOSTER COMPANY

3. Southern Mills Incorpo.ated

The second company to prepare needled felts from the pre-hydrophobed 1 denier Acrilan was Southern Mills Incorporated of Atlanta, Georgia. The samples obtained from this source were found to have been exceptionally well carded and needled, but were excessively heavy (i.e., the areal density was far greater than requested). Portions of this needled felt were compartmented in the laboratory and buoyancy values obtained for the resultant filler. The buoyancy curve representative of these compartmented samples is presented in Figure IX. Again it can be seen that the ultimate buoyancy was little less than anticipated or possible.

4. The Orr Felt and Blanket Company

The Orr Felt and Blanket Company of Piqua, Ohio, had also processed the pre-hydrophobed Acrilan into a needled felt. Due to a temporary lack of sewing equipment the felts were not compartmented at the plant but were ultimately compartmented in the laboratory at Mellon Institute. The results of the buoyancy evaluation on this material are presented in Table II. No appreciable buoyancy after five minutes of immersion was noted. A possible cause being oil contamination during the carding step, it was decided to dry-clean with CCl_4. It is quite apparent

TABLE II

Static Buoyancies Of Needled Felts, Containing Pre-Hydrophobed 1.0 dpf Acrilan Fibers, Prepared by The Orr Felt and Blanket Company and Compartmented at Mellon Institute

Immersion Time (Min.)	Buoyancy (#/# Compartmented Fill) Compartmented As Received	Compartmented and Dry-Cleaned with CCl_4
0.5	2.54	8.80
5	0	6.16
10	---	5.64
20	---	5.29
30	---	5.06
60	---	4.66

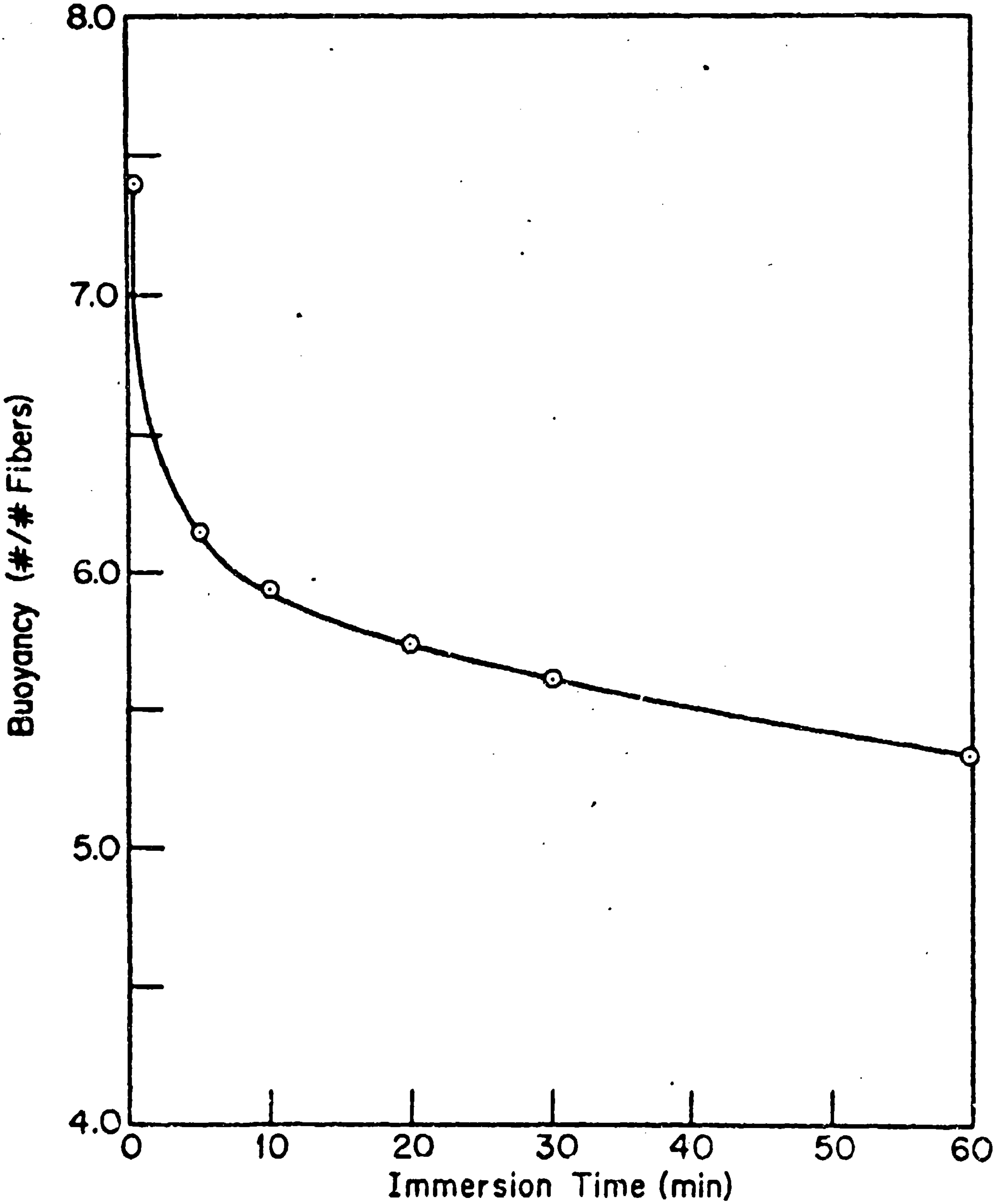


FIG. IX

STATIC BUOYANCIES OF NEEDLED FELTS, CONTAINING PRE-HYDROPHOBED 1.0 dpf ACRILAN FIBERS, PREPARED BY SOUTHERN MILLS INC. AND COMPARTMENTED AT MELLON INSTITUTE

as evidenced by the data presented in Table II that the main source of trouble in the inadequate buoyancy was due to some type of CCl_4-soluble impurities.

5. The American Felt Company

Considerable success in all phases of processing was encountered by The American Felt Company of Glenville, Connecticut. The minor obstacles that occurred during carding, needling and compartmenting were easily overcome resulting in very acceptable products. Four groups of compartmented hydrophobed 1.0 dpf Acrilan felts were prepared with areal densities of 11.0 oz/yd^2, 14.0 oz/yd^2, 14.6 oz/yd^2 and 16.0 oz/yd^2. Table III contains the results of the buoyancy tests performed upon these materials.

II. Commercial Preparation of 1.0 dpf Acrilan Felts with Laboratory-Applied Water-Repellent

a. Western Felt Works

1. Applicatic if Water-Repellent at Mellon Institute

During the trial runs at the various textile processors, a quantity of 1.0 dpf Acrilan fibers was hydrophobed in the laboratory at Mellon Institute and supplied to the Western Felt Works, Chicago, Illinois, for carding and needling into felts. Prior to forwarding, the

TABLE III

Pre-hydrophobed 1.0 dpf Acrilan Felts (Compartmented)

Prepared Commercially by the American Felt Company

Immersion Time	Buoyancy (#/# Fill)			
	11.0 oz/yd^2	14.0 oz/yd^2	14.6 oz/yd^2	16.0 oz/yd^2
0.5 Min.	3.50	8.61	9.02	8.73
5	7.20	7.10	7.51	7.32
10	6.86	6.81	7.28	7.00
20	6.17	6.25	6.89	6.78
30	6.06	6.11	6.72	6.47
60	5.80	5.87	6.62	6.29
24 Hrs.	4.98	5.01	6.05	5.08
Δ_{24}	3.52	3.60	2.97	3.65

effectiveness of the water-repellency was evaluated. Samples were carded in the laboratory and then subjected to the microstatic buoyancy test. The buoyancy was found to be adequate (Figure X); and, therefore, the performance of the finished felt would be dependent completely upon the preparation by the processor.

2. Effectiveness of the Felt

(a) Influence of Anti-Static Finish

Difficulty was immediately encountered during the early carding of the hydrophobed fibers by the personnel at Western Felt Works. Repeated attempts at carding ever [illegible]ide[illegible] the supervision of an expert carding technician from the Chemstrand Company, were fruitless. The absence of anti-static bars was undoubtedly the reason for this difficulty. As a last resort a recommended anti-static agent, ethyl alcohol-soluble Igepal CO-430, was applied by spraying the uncarded hydrophobed Acrilan. After this application, the difficulty in carding ceased and cohesive webs were formed, built into batts and subsequently needled. The needling process was extremely successful. The needling procedure was as follows: Two battings of areal density 7-9 oz/yd^2 each were needled once on one side, placed together with the needled sides facing each other and the ultimate single batt needled once again on one side. This produced a finished product of areal density 14.9 oz/yd^2 and 0.32" in thickness, with

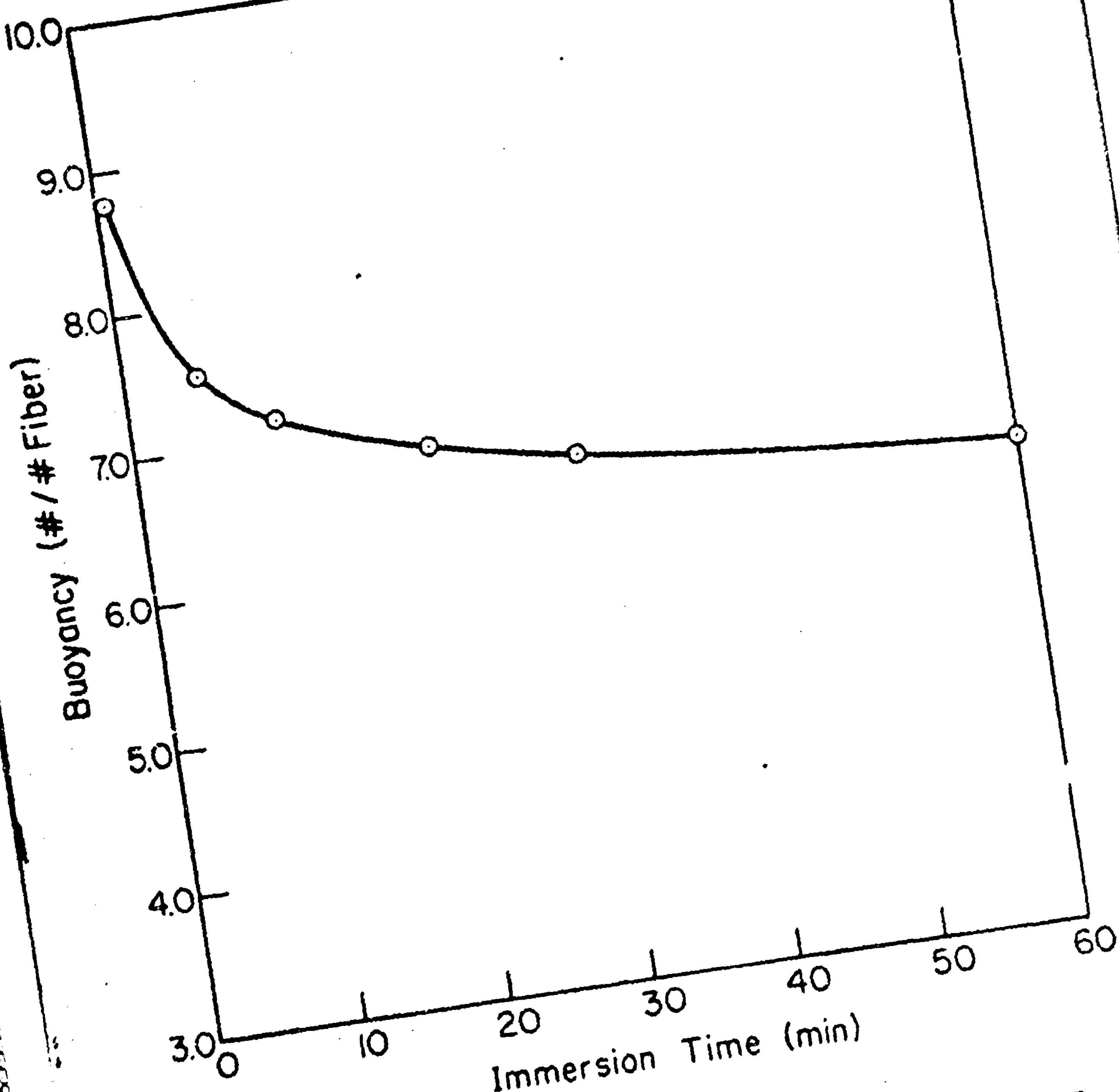


FIG. X

MICRO STATIC BUOYANCY (60gm. SAMPLES) OF ACRILAN (3.0"STOCK) HYDROPHOBED IN M.I. LABORATORY FOR PROCESSING INTO NEEDLED FELTS BY WESTERN FELT WORKS

an appearance on one side of a needled felt and on the opposite side of a carded batting.

The resultant felt was taken to the laboratory and tested for static buoyancy, using both the compartmented and uncompartmented (as is) forms. The buoyancies shown by these two groups of samples are depicted in the curves in Figure XI. The results were disappointing. However, from past experience it was surmised that the anti-static agent was masking the effect of the water repellency. Consequently samples were prepared in the compartmented state after being washed with ethyl alcohol for the removal of the Igepal CO-430, and then tested for their buoyancies. The data obtained from these last tests are presented also in Figure XI. It can be seen that the anti-static agent definitely had masked water repellency, and its removal resulted in a tremendous increase in the buoyancy exhibited by the contaminated compartmented felts.

III. Prototype Jacket Containing Compartmented Pre-hydrophobed Felt of 1.0 dpf Acrilan

Two prototype jackets, medium and large, were made by the donor, U. S. Naval Supply Research and Development Facility, for buoyancy evaluations. The liners were compartmented felts prepared by the American Felt Company from pre-hydrophobed 1.0 dpf Acrilan staple fibers. The sleeves were lined with 10-12 oz/yd^2 felt while the

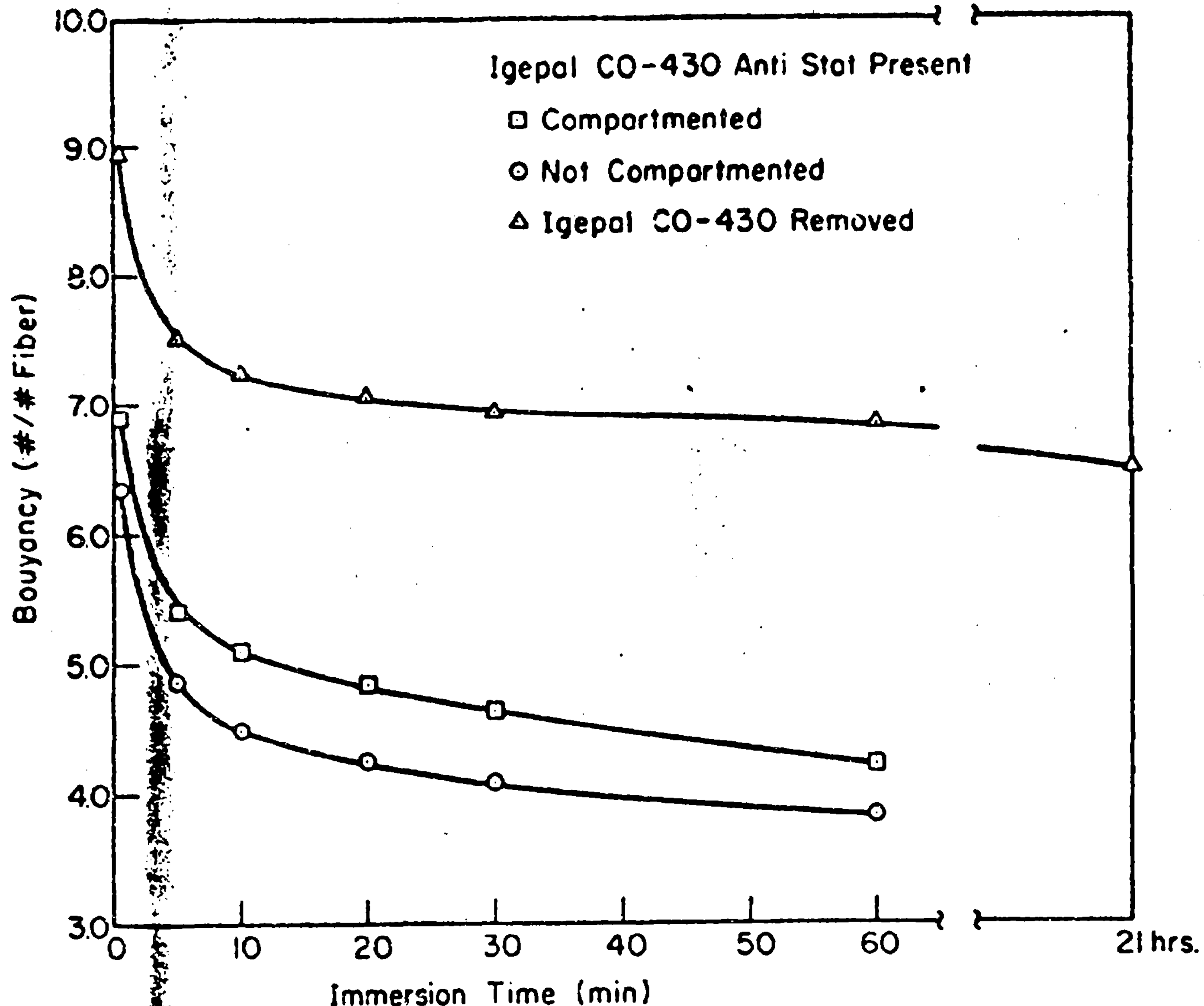


FIG. XI

BUOYANCY OF 1.0 dpf ACRILAN FELTS HYDROPHOBED AT M.I. AND NEEDLED AT WESTERN FELT WORKS

main body of the jackets contained 14-16 oz/yd^2 felt. The total weight of each liner was 1-1/2 lbs.

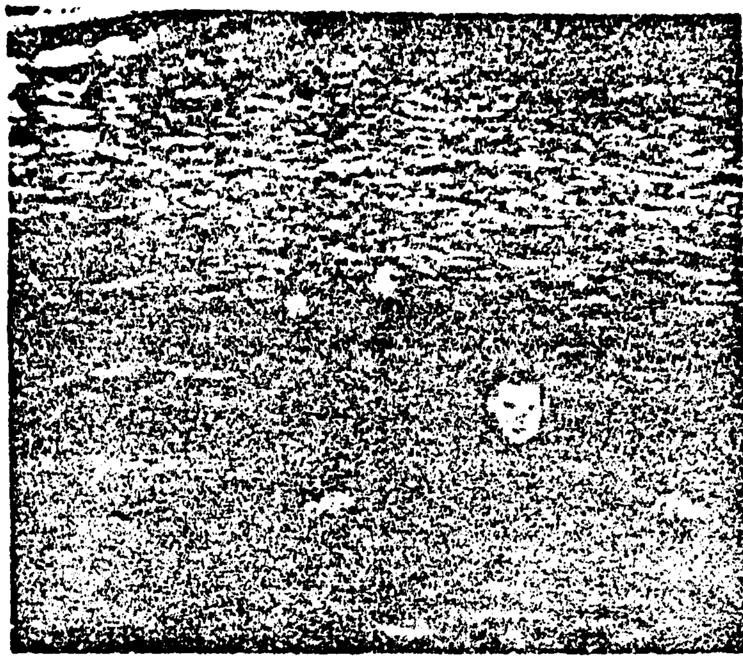
a. Pool Test

Several personnel from Mellon Institute volunteered to wear the jackets in the dynamic pool tests conducted at the Trees Pool, University of Pittsburgh. The accompanying photographs depict the clothes worn and the men in the water after a period of 20 minutes. Immediately after this period of immersion, both subjects noted a marked loss in buoyancy.

b. Static Buoyancy Evaluation

1. Effect of Additional Lining

For correlation with the pool test, the medium jacket was subjected to the laboratory static buoyancy test after being spun and dried. The resultant curve is presented in Figure XII. The jacket had an initial buoyancy slightly in excess of 6-1/2 lbs., and after 20 minutes of immersion dropped well below 4 lbs. However from our previous laboratory tests, it had been concluded that 2 lbs. of compartmented fill are the minimum requirement. Consequently 1/2 lb. of the compartmented Acrylic felt was added. This was distributed in the jacket in the following manner: a 1/4 lb. strip was placed in the back below the shoulders, and two strips (1/8 lb. each) positioned in the front at the



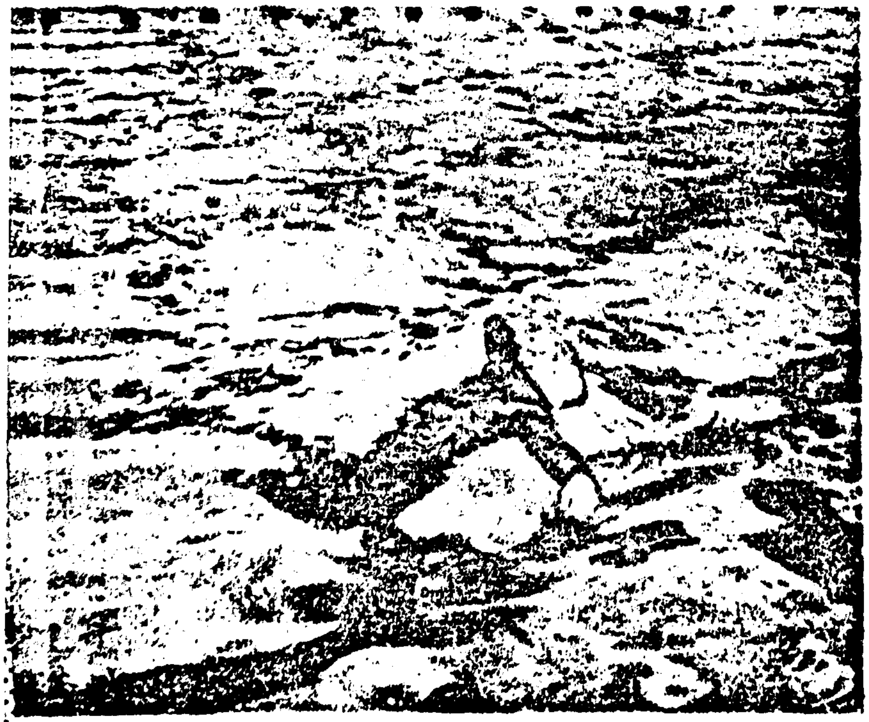
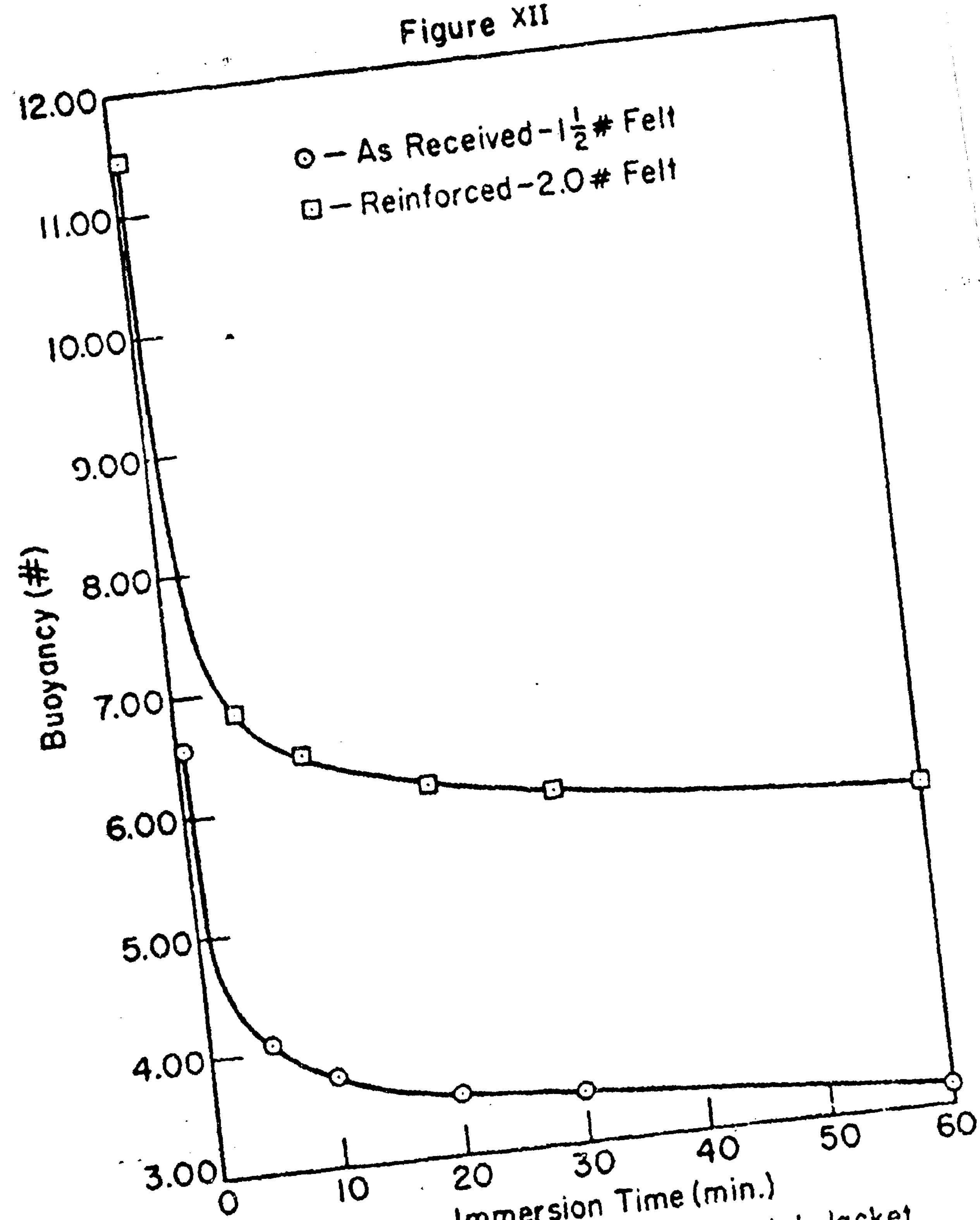


Figure XII



Static Buoyancy of an Experimental Jacket Containing Compartmented Felt Utilizing Pre-Hydrophobed 1.0dpf Acrilan Fibers

breast. The remarkable increase in buoyancy is shown by the curve in Figure XII. Even after a period of 60 minutes, the jacket with the 2 lbs. of felt had a buoyancy of 6 lbs.

B. BALLISTIC EVALUATIONS

1. Needled Felts Prepared from Pre-hydrophobed 1.0 dpf Acrilan

a. Laboratory-Prepared Felts

In the past ballistic tests have been performed upon the Acrilan felts which had been hydrophobed batchwise in the laboratory. It was therefore necessary to evaluate the ballistic effectiveness of the Acrilan fibers which had been pre-hydrophobed by the Chemstrand Company during preparation prior to cutting into staple form. In the accompanying Figure XIII a ballistic efficiency curve is presented representative of a needled felt containing the one denier Acrilan fibers which had been pre-hydrophobed. The felt in question had physical measurements as follows: 0.40 inches in thickness and an areal density of 15.8 oz/yd^2. The comparison of this representative curve with previous ballistic curves for the laboratory hydrophobed Acrilan felts show that there is no essential difference in their performances.

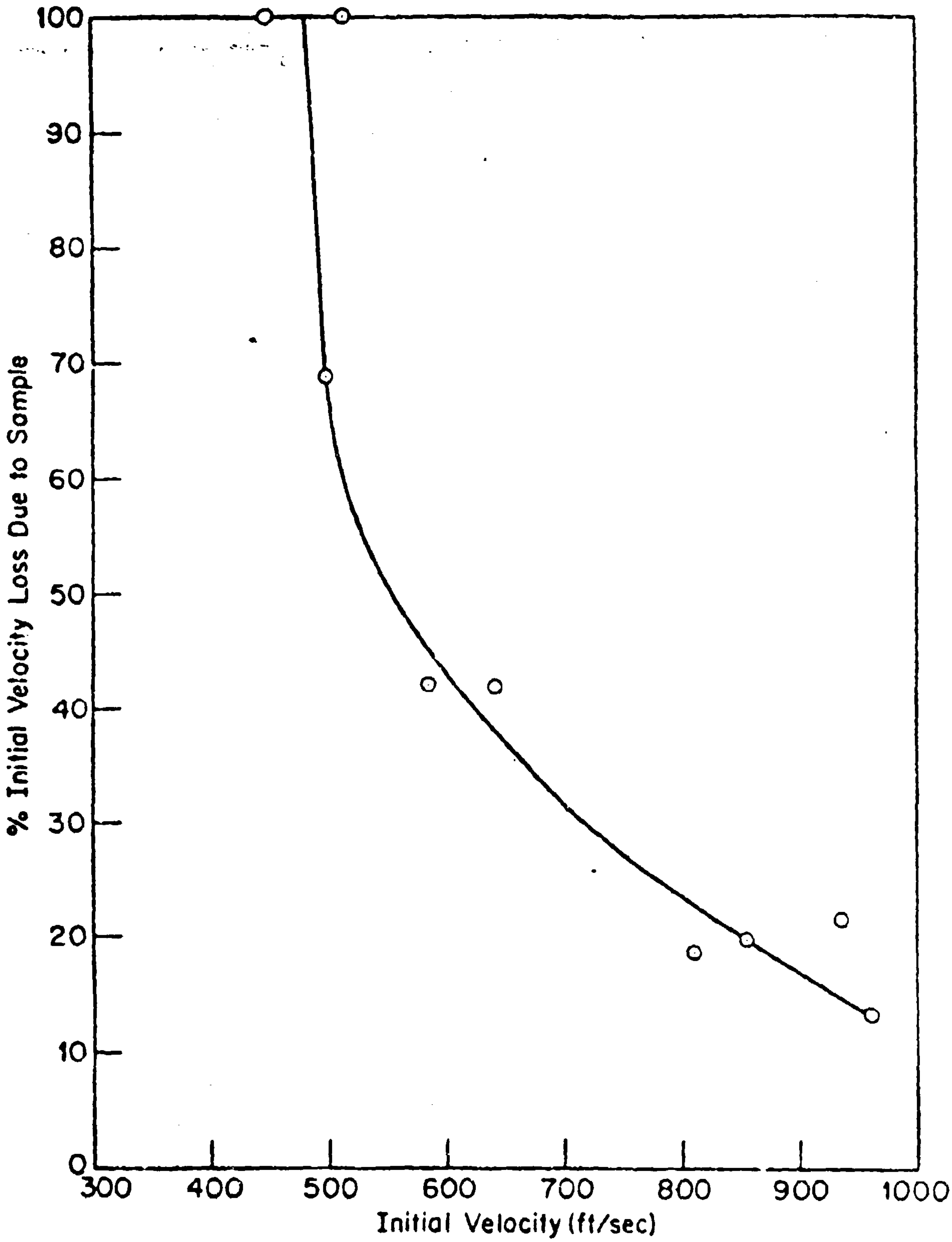


FIG. XIII

BALLISTIC EFFICIENCY CURVE FOR A NEEDLED FELT, 0.40" THICK AND 15.8 oz/yd^2, CONTAINING PRE-HYDROPHOBED ACRILAN STAPLE FIBERS, 1.0 dpf

b. Prototype Jacket Components

The ballistic effectiveness of the prototype jacket was determined. The outer shell (encountered the test pellets first) was an 8 oz/yd^2 Cotton-Nylon (50/50) cloth with the Quarpel water-repellent finish. The compartmented felt was exactly 14.6 oz/yd^2. The inner cloth lining was of a light nylon, closely woven. The ballistic efficiency curve is presented in Figure XIV.

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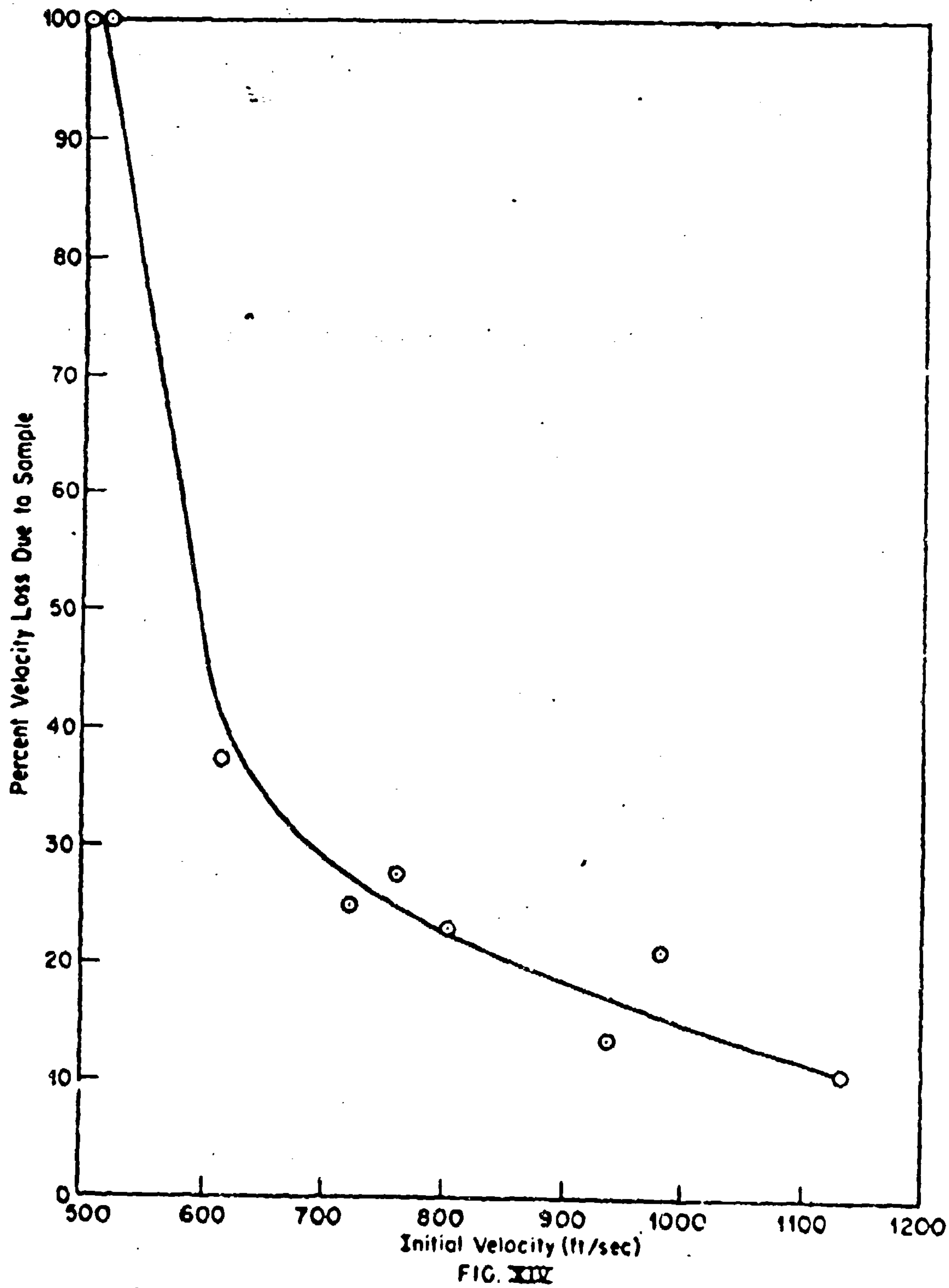

FIG. XIV
BALLISTIC PERFORMANCE OF THE NAVY PROTOTYPE JACKET
CONTAINING PREHYDROPHOBED 1.0 dpf ACRILAN FELT (COMPARTMENTED)